A PREFERRED THICKNESS LINE ACCOMPANYING MULTIPLE TORNADO OCCURRENCES

CONRAD P. MOOK
Weather Bureau Airport Station, Washington National Airport, Washington, D. C.

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The purpose of this note is to call attention to a preferred 1,000–500-mb. thickness line that in the mean accompanies multiple tornado outbreaks in the United States.

Studies by Sutcliffe [1] and others have suggested that thickness patterns are a suitable synoptic tool for obtaining a picture of the three-dimensional structure of the atmosphere. Sutcliffe and Forsdyke [2] have placed particular emphasis on charts showing the pattern of thickness of the 1,000–500-mb. layer. The contribution of the thickness pattern and the synoptic pressure patterns to the vorticity of the tornado is outside the scope of the present study. However, though much has been written concerning the value of such patterns in the evaluation of vertical motion and synoptic development, there has been little mention of the possible forecasting significance of the position of particular thickness lines, which are equivalent to the mean temperature of the air columns considered.

That a preferred thickness line should accompany tornado outbreaks may be inferred from the findings of several investigators and is a vital part in a possible mechanism for the generation of violent vertical convection that is here postulated. This mechanism is pictured as an air column of given mean temperature in the troposphere being restrained to that mean temperature while at the same time warm air is being injected into low levels; this produces an air column which is extremely unstable in the vertical. Unpublished studies, made by the U. S. Weather Bureau at Memphis, Tenn., under the supervision of Mr. Gilley T. Stephens, have shown that during tornado occurrences in that area such a condition does apparently prevail. At 500 mb. the temperature holds constant between −10° and −16° C. and at 850 mb. there are large positive increases in temperature and humidity. Therefore, since it is known [3] that most tornadoes occur with surface dew points exceeding 55° F., there probably exist various sets of mean air column temperatures such that introduction of such high moisture values at low levels would create vertical instability.

A mechanism for holding the mean temperature, or as we shall see "thickness," pattern constant during such an intrusion of "warmer" air at low levels can be visualized as being of two possible types. First, the thickness lines could be very closely spaced indicating a marked temperature contrast and a mass of cold air near the ground which would offer some frictional resistance to rapid displacement. Secondly, the approach of stronger winds at the 500-mb. level in the direction of the thickness lines would tend to maintain the strong wind shear represented by the thickness lines, thus furnishing a possible mechanism for maintaining, temporarily at least, the "status quo" of the thickness pattern. Some support for the latter view is found in a study by Schmidt [4] of tornado forecasting for western Tennessee and western Kentucky. He has found that one necessary prior condition to the occurrence of tornadoes is an increase in westerly momentum at 500 mb. to the west of the area.

Some further evidence of the possible existence of a set of preferred thickness lines can be deduced from (1) Fletcher's [5] discovery that wind maxima or "jets" at 500 mb. tend to follow preferred contours, and (2) the known connection between tornadoes and relatively low sea-level pressures or 1,000-mb. contours.

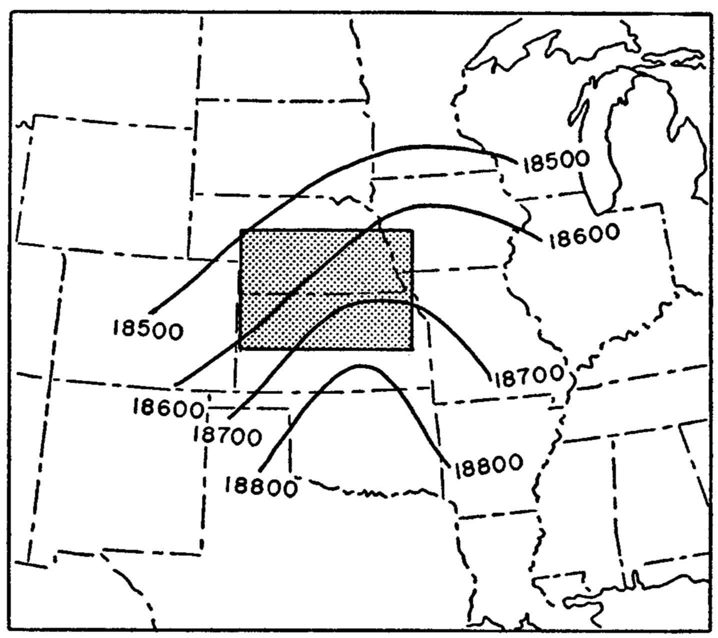

FIGURE 1.—1,000–500-mb. thickness computed from composite charts of 13 tornado situations in the shaded area.

It was therefore decided to make a preliminary determination of the possibility of the existence of such a line, or lines, through a study of composite thickness patterns associated with tornadoes.

The Weather Bureau [6] has prepared charts showing composite contour patterns which accompanied, or preceded by not more than 12 hours, multiple tornado outbreaks in five areas of the Midwest and South.[1] From the composite 1,000-mb. and 500-mb. patterns thus furnished the 1,000–500-mb. thickness patterns were constructed for the five areas shown in figures 1 through 5. Note the consistent presence of the 18,600-ft. thickness line in each area. This line, incidentally, has been found also to be roughly parallel to the normal tracks of tornadoes in the areas shown.

The relationship shown here is, of course, a relationship between the averages of groups of data and not between individual cases. On the basis of the arguments previously given it would appear that there should be combinations of 1,000–500-mb. thickness and low level humidity involving thickness patterns other than those in

[1] A "major tornado day" or multiple tornado outbreak was arbitrarily defined for inclusion in the composite data [5] as one in which three or more tornadoes occurred in one area when at least two of these tornadoes were separated by a distance of 100 miles or more. There were a few days included in these data in which a "major tornado day" occurred in two areas so that data in these cases were included twice. Most of the occurrences during the six tornado seasons (March through June) of 1945 through 1950 that met the requirements for a major tornado day were used.

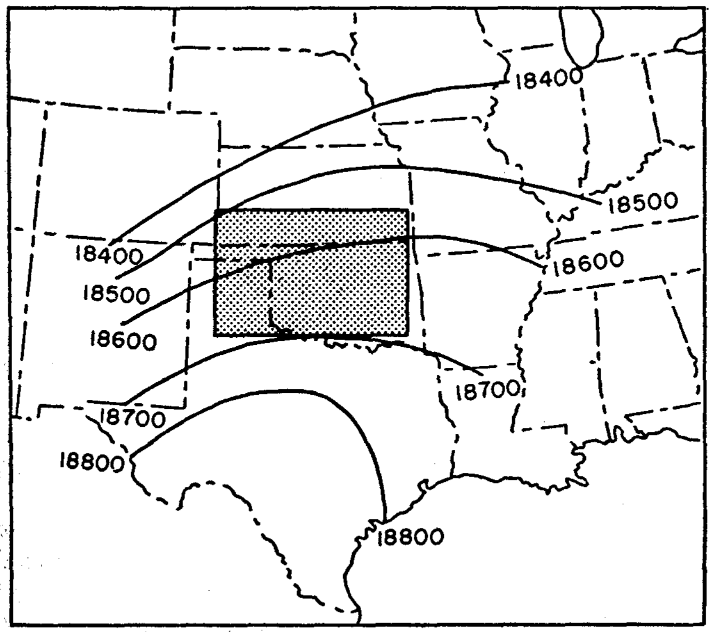

FIGURE 2.—1,000–500-mb. thickness computed from composite charts of 28 tornado situations in the shaded area.

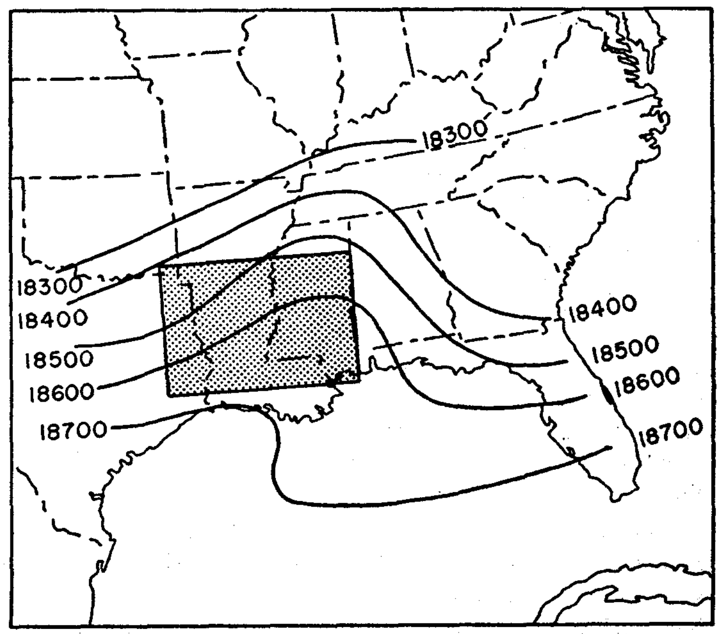

FIGURE 4.—1,000–500-mb. thickness computed from composite charts of 10 tornado situations in the shaded area.

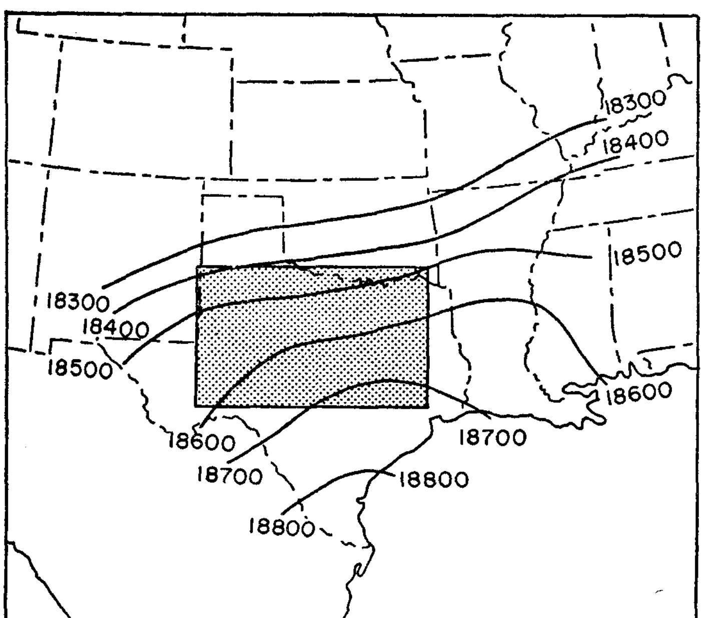

FIGURE 3.—1,000–500 mb. thickness computed from composite charts of 13 tornado situations in the shaded area.

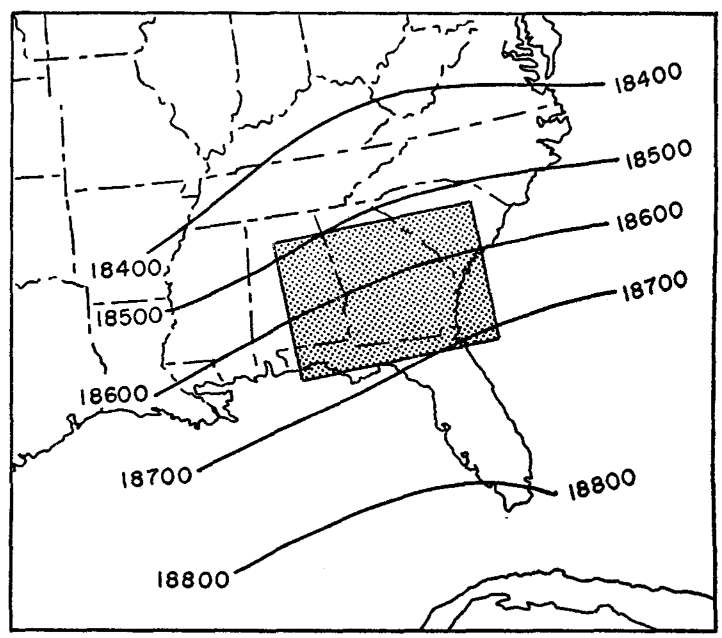

FIGURE 5.—1,000–500-mb. thickness computed from composite charts of 8 tornado situations in the shaded area.

the immediate vicinity of 18,600 ft. which would result in instability. It would also appear that the indicated strong thickness gradient would not always be a necessary accompaniment of the 18,600-ft. line. Examination of daily thickness charts and tornado data for March 1954 shows this to be true while at the same time continuing to point to the special significance of the 18,600-ft. line. During the first part of March 1954 this line remained south of the United States east of the Rockies until 1500 GMT of the 10th when it appeared in the Texas-Oklahoma Panhandle area. By 0300 GMT of the 12th it had reached northward just beyond Oklahoma City and by 1500 GMT of the 12th it was located just north of Memphis, Tenn. However at that time the strongest thickness gradient in that general area lay just to the north of the 18,400-ft. thickness line which at that time extended eastward from Kansas to Illinois. Tornadoes were reported in both Kansas and Illinois on the afternoon of March 12. Elsewhere east of the Rockies the only tornadoes during the first 12 days of March occurred on the previous day, March 11, in Kansas. On March 13, 1954, at 1500 GMT the 18,600-ft. thickness line was oriented east-west through central Georgia and was accompanied by a severe tornado outbreak in that area. Similar results are to be found later in March except that on March 19 a tornado which was associated with unusually low humidites occurred in Ohio near the 18,000-ft. thickness line. Sugg and Foster [7] point out that the tornadoes of May 1, 1954, in Oklahoma occurred in the vicinity of the 18,600-ft. thickness line.

The strong gradient of the composite thickness lines as shown in these figures is also consistent with Newton's [8] suggestion concerning the possible application of the earlier work by Durst and Sutcliffe [9] to the formation and maintenance of squall lines.

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